

Permit Evaluation and Recommendations

Prepared for Carmel Olefins
27/12/17

Table of Contents

Background	1
Evaluation and Recommendations.....	1
Destruction Efficiency (DE)	
Steam to Gas Ratio	
Definition of Oversteaming	
Smoke Definition	
Automatic Steam Control	
Flare Gas to Ethylene Ratio	

Background

Carmel Olefins contracted Clean Air Engineering to evaluate language on flare operations in a draft permit for their Haifa, Israel facility. [REDACTED] has been engaged in the US with flare issues for a decade working with refiners and chemical companies complying with EPA's flare initiative. [REDACTED] has also worked with [REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

Evaluation and Recommendations

Destruction Efficiency (DE)

Section 10(A)(2) of the draft permit states "The flares should be operated in a manner that ensures ... destruction efficiency of at least 99%."

There is no practical way to directly determine on-going compliance with any DE specification. Therefore, a flare operator can only rely on flare operating practices that have demonstrated high combustion efficiency results in prior research programs. To my knowledge, there are no established operating practices that will ensure flare DE equal to or greater than 99% on a consistent basis. However, numerous studies¹ have shown that operating practices exist that will ensure 98% DE on a consistent basis. This 98% DE standard has been adopted by US EPA in its Refinery Sector Rule (RSR) [80 FR 75178] and will also be incorporated in its upcoming Ethylene Rule. The following quote is taken from the RSR rule.

"The agency believes, given the results from the various data analyses conducted, that this operating limit is appropriate, reasonable and will ensure that refinery flares meet 98-percent destruction efficiency at all times when operated in concert with the other suite of requirements refinery flares need to achieve (e.g., flare tip velocity requirements, visible emissions requirements, and continuously lit pilot flame requirements)."

The 99% value in the permit may have originated with the Large Volume Organic Chemical (LVOC) BREF issued in 2003 by the European Commission. We note that this document is conflicted on the destruction efficiency of elevated flares. In Section 6.4 of the BREF Table 6.1, a Best Available Technology "associated level" is shown for elevated flares as DE>99%. However, in the Flaring Annex (Annex III), reproduced below as Table 1, another value is shown... DE > 98%.

¹ For example, tests conducted by the Texas Commission on Environmental Quality (TCEQ, 2010) and by numerous refineries and chemical plants as part of the US Environmental Protection Agency (EPA) flare initiative. These tests occurred from 2009 through 2015 at various facilities. Clean Air has been involved with all of these research programs.

Table 1: Excerpt from LVOC BREF (2003)

Issue	Elevated flares	Ground flares
Capacity	Up to hundreds of tonnes per hour	Up to tens of tonnes per hour
Advantages	Quick and safe release of large amounts of gases. Low emission concentrations in case of malfunction of the flare.	Less flame visibility. Less noise. Better combustion (less soot). More reliable ignition (less affected by wind). More flexible to gas flow variations in the low range
Efficiency for VOC	>98 % under optimal conditions. 0 - 98 % under sub-optimal conditions.	>99 % under optimal conditions. 0 - 99 % under sub-optimal conditions.
Disadvantages	Light nuisance. Noise nuisance. Difficulties in handling low flows.	Limited capacity. Increased safety risks when malfunctioning. Potentially reduced efficiency due to often poor fuel quality.

Comparison of elevated and ground flares

However, on 22 December 2017, a new LVOC BREF was adopted by the European Commission. This new version replaces the 2003 version. In the 2017 version, all references to a flare DE BAT have been removed. The flaring Annex has also been removed. Therefore, at this point in time, the EU does not recognize a BAT value for flare DE at LVOC facilities.

Recommendation: Change the minimum DE requirement from 99% to 98%. This value is consistent with research results, consistent with US EPA regulations, and does not conflict with current European BAT guidance.

Steam to Gas Ratio

Section 10(A)(6) of the draft permit states "Steam should be injected to the flare at all times for efficient mixing of the air and the flow of hydrocarbons in a suitable ratio of steam output to hydrocarbon output and in accordance with the manufacturer's instructions, taking into account the composition and output of gases in the flares, all in a manner that results in compliance with the conditions of subsection (2)."

The steam on a steam-assisted flare serves two major functions: 1) provides cooling for the flare tip to minimize thermal degradation, and 2) inspirates air and provides additional turbulence to minimize smoking. Each flare vendor specifies the "minimum steam" required for cooling (Function 1). This value is typically found in the flare specifications provided by the vendor as a steam to gas ratio. This value has nothing to do with operating steam – that is, the steam needed on a day-to-day basis to operate the flare in a smokeless manner (Function 2). The minimum steam value also is not directly associated with any environmentally-related parameters such as DE. It is strictly used as a maintenance guideline for the flare operator.

Carmel Olefin Permit Evaluation

The operating steam is not specified by the vendor since a wide range of steam to gas ratios are necessary for proper flare operation. The operating steam ratio may be many times the minimum steam ratio without significantly affecting DE assuming the flare is operated correctly with regard to the other parameters specified in the permit (minimum heat values, pilots on, etc.). Therefore, the referenced permit language requiring the steam to gas ratio be “in accordance with the manufacturer’s instructions” has no meaning in an environmental context.

Recommendation: Eliminate the language requiring that the flare steam to gas ratio be “in accordance with manufacturer’s instructions.”

Definition of Over-steaming

Section 10(A)(6) of the draft permit states “...the Emission Source Owner should avoid oversteaming.” I very much agree with this statement. However, the question is: “What constitutes oversteaming?”

This has been a question the US EPA has been researching since the 1980’s. More recently (from 2009 to present), a series of tests has been conducted on a variety of flare types and gas compositions specifically to answer that question. I have been involved with all of these tests and can draw some conclusions based on the results.

Other language in the draft permit suggests that a steam to gas or steam to hydrocarbon ratio is an appropriate method of assessing oversteaming (although no specific value is given). However, the research suggests that any type of steam ratio is unreliable for predicting high DE. Figure 1 shows a summary of several tests on several flares with a variety of flare gas compositions.

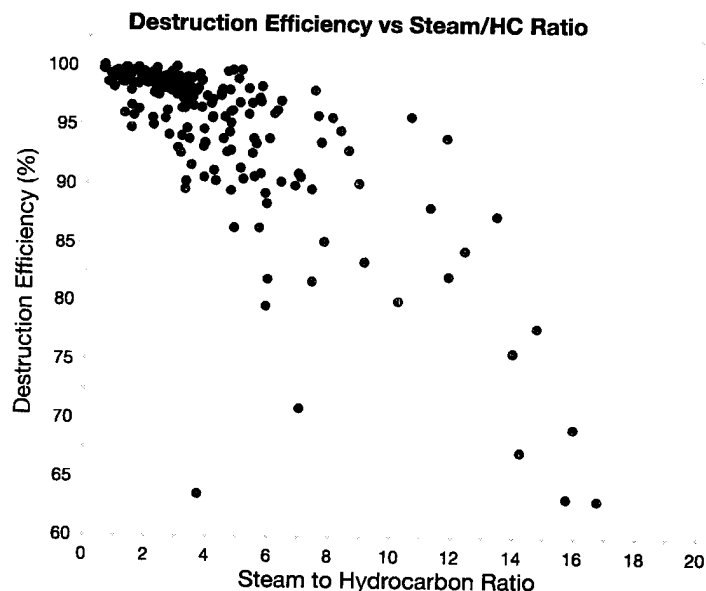


Figure 1. DE vs S/HC Ratio for a variety of flares over a range of conditions and gas compositions. Color bar represents DE > 98%. Data consolidated from various EPA mandated tests 2009-Present.

Note that DE > 98% can occur anywhere from a S/HC = ~1 to S/HC = ~5 depending on the flare and gas composition. Also note that DE falls off at very different rates for different tests as well. For flare gas that is very consistent in composition, it may be possible to develop an effective S/HC ratio as an indicator of high DE. For flares with varying composition, this is likely not possible. Also, using a steam to hydrocarbon ratio ignores the significant contribution of even small amounts of hydrogen in the flare gas. Hydrogen has an outsized effect on flare DE compared to its heating value. It also acts as a smoke suppressor meaning less steam is necessary when hydrogen is present.

If a steam ratio is not the best way to determine oversteaming, then what approach will work better? This question does have an answer. However, a closer look at your flares will be required to provide a specific answer. US EPA regulations, particularly the Refinery Sector Rule may provide guidance here since that rule is based on the findings of the research referenced earlier.

Recommendation: Develop a clear specification that defines oversteaming to eliminate any potential for uncertainty as to when the flare is operating with the appropriate amount of steam and when it is not.

Smoke Definition

Section 10(A)(2) of the draft permit states "The flares should be operated in a manner that ensures combustion without any visible smoke..." You mentioned that the original permit used the Ringelmann scale rather than a visible smoke standard. In the US, the Ringelmann scale has been obsolete for many years. There are no standards that use that approach to opacity or visible smoke evaluation. "Visible smoke" has been the qualitative standard for smoke evaluation in the US since EPA Method 22 was adopted in 1982.

The text of Method 22 specifically references smoking flares. It defines "smoke emissions" as

"... a pollutant generated by combustion in a flare and occurring immediately downstream of the flame. Smoke occurring within the flame, but not downstream of the flame, is not considered a smoke emission."

The practical interpretation of this definition is more complex than it may seem. First, research has definitively established that flames that are dark orange with black "marbling" are extremely high efficiency flames. Flames with these characteristics are described as being at the "incipient smoke point." This is a desirable operating condition. A person unfamiliar with proper flare operation may believe that dark matter in the flame zone is a smoking flare. It is not according to the Method 22 description.

To complicate matters further, often flare flames are not contiguous. Eddies form in the flame zone and separate from the main visible flame. When these eddies contain dark streaks, they may be interpreted by some as a smoking flare. See Figure 2.

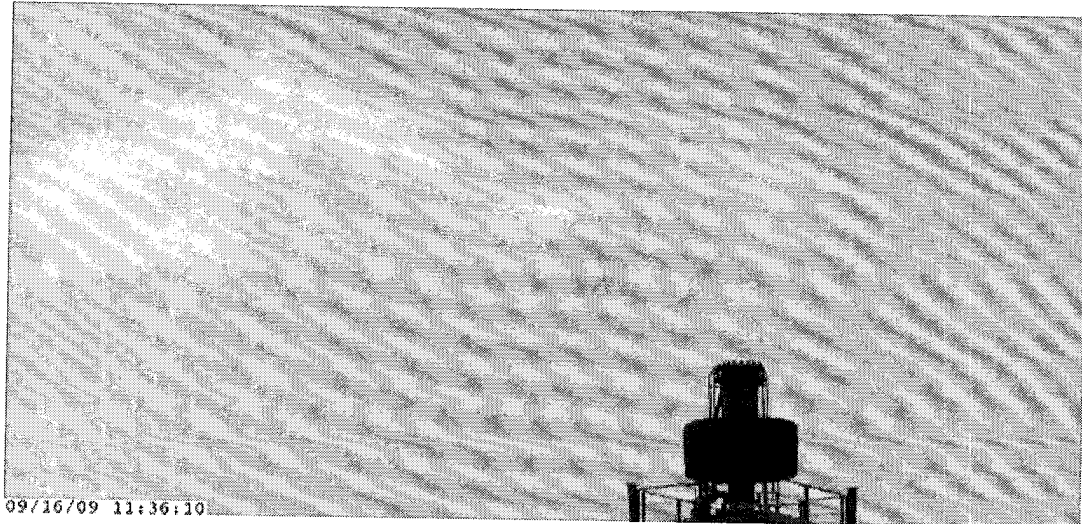


Figure 2. Image of a flare at its incipient smoke point. This flame is characteristic of high DE and should not be considered a smoking flare.

Again, this is not a smoking flare according to the definition in Method 22. The eddies breaking away from the main flame contain dark streaks but it is clear from the orange color that combustion is still occurring. In this case, the dark material will disappear when the visible flame disappears.

Visible emissions are a difficult issue for flares. There is currently no technology, including the human eye, that can reliably detect a smoking flare under all conditions. We have tested many cameras and other devices and algorithms that claim to be able to do this, but under rigid test conditions, all have failed. The approach taken by flare operators in the US is simply to have a camera pointed at the flare and have operators note in a manual log the start and stop time of any observation of visible emissions trailing from the flare. This method is not effective at night, but it is all we have.

Regarding the cumulative 120 hours per year in the draft permit language, there is no regulation that I am aware of in the US or anywhere else that contains this operating restriction.

Recommendation: The “visible smoke” terminology is standard in the US for all flares and many other potential emission sources and replaces the obsolete Ringelmann charts. I would recommend using an operator log noting start and stop times of any visible smoke from the flares. Also, remove the 120-hour limitation as it seems to lack precedent.

Carmel Olefin Permit Evaluation

One other note on visible emissions... Section 10(C)(4) of the draft permit states in reference to the cameras used to record the flare flames "The cameras will record at a rate of at least 24 images per second..." This requirement means Carmel Olefins must invest in very large and potentially expensive storage equipment for these videos. In my opinion, 24 frames per second is not necessary to determine compliance with a five-minute visible emission standard. EPA's Refinery Sector Rule requires one frame every 15 seconds. This should be ample to ensure compliance. In each five-minute period 20 flare images will be recorded.

Automatic Steam Control

There is language in the draft permit that requires a control system for the steam to gas ratio to ensure high DE. There are two issues with this language. The first is that steam ratios are probably not the best approach to ensuring high DE (see discussion in oversteaming section above). Steam ratios are not used in any EPA regulations for that reason. The second issue is that automatic steam control systems for flares are notoriously difficult to implement. Many have tried, most have failed. One of our clients has been working on such a system for their refinery for 7 years and it still has problems. There are companies that claim they have technology to accomplish this but none of them we have evaluated work consistently.

The problem with automatic steam control is that the balance between understeaming the flare (and thus generating smoke) and over-steaming the flare (resulting in reduced DE) constantly shifts depending on the changing gas composition. Automatic steam control may be achievable for flares with very constant gas compositions but becomes increasingly difficult as gas composition variability increases.

While many refiners and chemical plants in the US are experimenting with automatic steam control very few are actually using it for day to day plant operation. Instead, they rely on plant operators and manual control.

Recommendation: Remove the requirement for automatic steam control from the draft permit language. It is not a practical approach for most plants.

Flare Gas to Ethylene Ratio

Section 10(F)(6) of the draft permit states "Targets for maximum process recovery of the gases, so that the ratio of gas transmitted to the monomer flare during routine operation, malfunction, shutdown and startup will be less than 15 kg per ton of ethylene produced on an annual average."

This language is taken from the LVOC BREF (2003) document. This document mentions that this ratio may be achievable "under optimum conditions." It does not define these conditions so it is not known whether the Carmel Olefins flare is capable of complying with this requirement.

However, the 2003 document may no longer be relevant to this issue. As mentioned above, the European Commission has adopted a new version of the LVOC BREF as of

Carmel Olefin Permit Evaluation

22 December 2017. This new version replaces the 2003 version. In the 2017 version, the flaring limitation language has been removed. There is no process efficiency limitation on flare gas generation in the new version.

For comparison, US EPA has established some flaring caps but generally these are site-specific flare caps established from a baseline of operating data. They are not generic industry-wide limitations as is the case with the now rescinded LVOC BREF caps.

This requirement also appears to be somewhat redundant. There are already flaring limitations established in the draft permit language in Section 10(A)(8).

Recommendation: Eliminate the 15 kg per ton of ethylene produced limitation. This was a generic “best case” limit that may or may not be applicable to the Carmel Olefins flare. It is taken from a BREF document that is no longer current.